A PRELIMINARY STUDY OF NON-FERROUS CONVERTER OPERATION AND EMISSION CONTAINMENT (DEC. 1983)

BY

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FOR

Environmental Protection Service
Environment Canada

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ABSTRACT

The role of the converter in the nonferrous metallurgical process is summarized. The various types of converters used in the copper and nickel industry are reviewed with emphasis on the emission of sulphur dioxide.

Examples of the newer designs for primary and secondary hoods are given. The problems associated with various gas cooling and cleaning systems are discussed, with particular reference to the converter.

Sulphur fixation of converter gases, usually in the form of sulphuric acid, and new and emerging technology having an impact on sulphur containment, are reviewed.

1 INTRODUCTION

1.1 SCOPE

On October 14, 1983 the Environmental Protection Service of Environment Canada awarded a contract (KE145-3-0513) to Jan H. Reimers and Associates Inc. of Oakville, having the following terms of reference:

1.1.1 Objective

To provide background information on the operation, emissions and methods of sulphur containment from nonferrous converters.

1.1.2 Period

October 17, 1983 to December 17, 1983.

1.1.3 Terms of Reference

(a) Review of current technology, including design, operation and characteristics of gases from currently used converters, including hoods, gas cooling and cleaning systems, and fixation of SO_2 from converter gases.

(b) Describe and comment upon new developments in this field, including:

- continuous converting systems
- smelting processes avoiding the converting operation and including comments on:
  - practicability
  - potential for emission containment and sulphur fixation
  - present status of development
  - suitability for application in existing smelters.

1.2 All three principals of Jan H. Reimers and Associates Inc. participated in this study.

1.3 RELEVANT EXPERIENCE OF JAN H. REIMERS AND ASSOCIATES INC.

The three principals of the firm are registered as Consulting Engineers under the provisions of Ontario Regulation 60-73, and are Professional Engineers in the Province of Ontario.

In their studies and consulting services to the nonferrous metallurgical industry, there has in recent years been increasing emphasis on the recovery of sulphur in one form or another. In the course of their work over the past six years they have visited nonferrous smelters and refineries in Europe, Australia, Japan and throughout North America. The plants visited have in many cases incorporated modern sulphur fixation techniques.

With respect to this particular study, the company carried out the Sulphur Containment Study (which was recently updated) as well as arsenic and mercury studies for Environment Canada. In recent years they have evaluated various types of converters for a number of clients including Texasgulf (now Kidd Creek Mines Ltd.), Roxby Management Services (joint venture of Western Mining Corporation, Australia, and British Petroleum Co.), Kennecott Minerals Company and Anaconda Copper Company in the United States, The Electrolytic Refining and Smelting Co. of Australasia, Codelco in Chile, Quimigal in Portugal, Elkem a/s in Norway, and others. A study of particular relevance in this connection is one we carried out in 1982 for Boliden Metall AB in Sweden, on the cleaning of their converter process and ventilation gases. In addition,

John C. Taylor of the firm served on the Peer Review Committee of the Royal Society of Canada, which reviewed documents prepared under the Canada/U.S. Memorandum of Intent on Transboundary Air Pollution.

2 SUMMARY

2.1 ROLE OF THE NONFERROUS CONVERTER

The primary smelting process, reverberatury furnace, etc., removes a proportion of the impurities in the concentrate, including sulphur. The resulting matte still contains iron, sulphur and minor impurities which must be removed in the converter before the final refining processes can be carried out.

Converting is a particularly important step in the processing of copper and nickel concentrates and is used in some commercial lead smelting processes.

Conventional converting treats the matte in two stages, the slag blow and the finishing blow. Consequently it is normally a batch operation, operating on a cycle period, which produces a variable volume of offgas whose SO_2 content varies with the cycle. With a conventional converter the normal operating variations are accentuated as the converter is turned out of stack to receive or discharge material.

2.2 COPPER OR NICKEL CONVERTERS

The Peirce-Smith converter is the most common unit used in the copper and nickel industry. While it is a very flexible unit, it does contribute significantly to the fugitive emissions in a smelter. Over the years other designs of converter have been developed to provide a more uniform flow and strength of offgas and reduce fugitive emissions. Those which are currently in commercial operation are:

(1) Hoboken syphon
(2) Top blown rotary, or Kaldo
(3) Mitsubishi continuous converting furnace.

Of the above only the Mitsubishi system is truly a continuous process; all the others operate on a batch basis with cycle periods ranging from 440 to 520 minutes/cycle.

Matte grade, crane service and production requirements will all have a significant bearing on the length of the cycle for any given size of converter.

The Hoboken syphon converter uses a syphon to remove the offgas and has the advantage of being able to accept matte while still blowing, thus reducing interruption of the gas flow during a cycle.

The top blown rotary converter is used in the copper, nickel and lead industries and, while expensive, is a very flexible unit.

The Mitsubishi furnace effectively controls emissions and is the only unit which produces a continuous flow of high strength gas. However, having no end point or finishing step, its ability to eliminate undesirable impurities is limited and its application is confined to relatively clean feed materials.

2.3 CONVERTER HOODS

The process offgases from the converting operation are collected in the primary hood. It is essential therefore that sufficient draft is provided to prevent gases bypassing the hood during normal operation. Since the hood is stationary and the converter must rotate "in or out of stack", clearance must be provided and this results in infiltration, or in-leakage, when adequate draft is provided.

Various primary hood designs have been put into commercial operation which provide for cooling and minimize infiltration. Among the more successful

designs are:

(a) Noranda waffle hood

(b) Mitsui converter housing

(c) Sumitomo system.

The Noranda hood is an air-cooled primary hood only, whereas the Mitsui and Sumitomo designs incorporate the water-cooled primary hood in the overall design to contain fugitive emissions.

Depending on the hood design and the ability to operate with a relatively close fit between the hood and the converter shell, the infiltration will be in the range of 120 to 150% of the volume of gas from the bath with new hoods, whereas the older designs allowed for 200% or more. This was to provide initial cooling of the gas but, when combined with additional in-leakage downstream, dilutes the gas strength to the 4% SO_2 range. By comparison, the Mitsui system will produce the following strength after gas cleaning:

Slag blow = 6% SO_2

Finishing blow = 8-9% SO_2.

To achieve these strengths and operate with the Mitsui system, careful control of the operation is required which may be difficult to achieve under North American conditions.

Sumitomo follows a different approach and use separate hoods to collect emissions at source. This could well have an advantage in the retrofit of existing smelters since the design allows some flexibility.

The Kaldo operations of Boliden in Sweden enclose the primary hood and the converter completely. This is considered to be maximum containment and

has proven very successful in containing lead emissions. With this approach they can reduce lead emissions in the working environment to 70 $\mu g/Nm^3$ and the system should be equally successful in containing SO_2.

Air curtains, on the other hand, are not as effective as other methods and have not been generally adopted by the industry.

2.4 CONVERTER GAS COOLING AND CLEANING

Offgases in the range of 1100 to 1200°C in the converter must be cooled before dust and entrained particles can be removed. Since the volume, gas strength and temperature vary with the converter cycle and the waiting period between cycles, a flexible cooling system is required. It is essential that the gas be cooled rapidly through the 640 and 570°C temperature range to minimize SO_3 formation and the corrosion which can result downstream from it. The final temperature entering the hot gas cleaning system, normally an electrostatic precipitator, must be above the dew point and within the design range of the gas cleaning equipment, normally 300 to 370°C.

2.4.1 Gas Cooling. Various gas cooling systems are used, but all have disadvantages of one sort or another. Those commonly in use are:

(a) Radiation coolers

(b) Air-to-Gas heat exchangers

(c) Waste heat boilers

(d) Evaporative coolers.

Radiation coolers lack the flexibility necessary to adapt to changing conditions and do not rapidly cool the gas through the critical range for

conversion of SO_2 to SO_3. Air-to-gas heat exchangers have the flexibility but can have problems in cleaning the tube banks. The most effective system, and also the most expensive, is the waste heat boiler adopted by most Japanese smelters.

Evaporative cooling is used in some smelters but control can be a problem and the water used for cooling will report as weak impure acid in the wet gas cleaning section of the acid plant.

2.4.2 Gas Cleaning. The gas cleaning system is designed to remove particulates and fume from the gas to maintain the recovery of values and provide a reasonably clean gas for sulphur fixation. Dust containing copper, nickel, lead and zinc will be returned to the smelter. Volatiles such as mercury, selenium and to varying degrees arsenic, will pass onto the wet gas cleaning system in the acid plant.

A certain amount of converter dust, particularly the coarse fraction, will be collected in the flues and cyclones, if present, but the fine dust is collected in an electrostatic precipitator. The gas cooling system is designed to provide a feed gas at the design temperature of the precipitator which is usually in the 360°C range.

2.5 SULPHUR FIXATION

The relatively low strength and varying volume of converter gases make processing to sulphuric acid the only practical alternative. The main problems to be overcome in the acid plant are the variation in SO_2 content, the fluctuating volume while the converter is in stack, and the interruption in flow when out of stack or on standby due to production or environment cutbacks.

The infiltration of ambient air, whether at the primary hood or as a result of lancing, soot blowing, etc. reduces the gas strength and increases the volume of gas supplied to an acid plant.

Increased volume and variable flow increase the cost of acid production from converters, over that from a continuous source.

2.6 NEW AND EMERGING TECHNOLOGY

New processes recently put into operation or currently under development take into account the problems associated with the fixation of sulphur from conventional converter offgases. The following classifies the developments under way at present:

New Converters:
- Kennecott's Solid Matte Oxygen Converting (SMOC)
- Humboldt-Wedag's CONTOP Converter

Combined Technology: Flash Smelting combined with the Mitsubishi Converting Furnace

Direct or Continuous Processes:
- Mitsubishi Continuous Process
- Noranda Process-Smelting to Blister
- Outokumpu Flash Smelting to Blister
- Reduction Smelting to Nickel Matte

All the above, with the exception of reduction smelting, are directed towards the production of copper. Reduction smelting has been applied to copper, for instance in the Brixlegg process and similar approaches. The top blown rotary converter, on the other hand, has been adapted by Inco for the treatment of nickel matte, smelter intermediates, and copper. Boliden Metall AB has applied similar units to the treatment of copper and lead materials.

In order to provide a more suitable offgas for acid production, the above processes will be less flexible in the elimination of impurities. This has already been the experience with the Noranda blister option and the Mitsubishi process. The application of these new processes to any specific operation will depend on the current and future impurity levels in concentrate and the need for flexibility in the smelter operation.

3 ROLE OF THE NONFERROUS CONVERTER

In a nonferrous smelter the primary smelting furnace, normally a reverberatory, flash, or electric furnace, removes a proportion of the sulphur and some other impurities. This is the first step in the extraction of values, but the smelting furnace product (normally furnace matte) still contains iron, sulphur and other impurities, such as As, Bi, Zn, etc., which must be removed before final refining can be carried out.

The role of the converter is primarily to remove the iron and adjust the sulphur to produce a product which is suitable for the downstream refining processes. At the same time certain impurities such as As, Bi, Zn, etc. can be eliminated to some degree, depending on the method of converter operation. Converting is a particularly important step in the processing of copper and nickel, and is found to a limited extent in some lead processes.

The converting process is carried out by blowing air, or oxygen enriched air, through submerged tuyeres into the molten furnace matte. Unlike the majority of smelting operations, the more common converting processes are batch operations. The treatment of matte in batches has the advantage of increasing the removal of certain impurities, but the disadvantage of producing an intermittent flow of SO_2 offgas.

In copper converting there are normally two distinct stages. For instance when treating a copper matte there is:

(a) Slag Blow - during which FeS is oxidized producing FeO, Fe_3O_4 and SO_2 with the heats of reaction maintaining the converter at the operating temperature in the range of 1200-1300°C.

Silica flux is added to slag the FeO as an iron silicate. This slag, also containing Fe_3O_4, is skimmed at intervals during the converting cycle.

The slag blow is finished when most of the FeS in the matte has been oxidized. The converter charge at this point will contain mainly Cu_2S, or white metal, with approximately 80% copper and 20% sulphur.

The time required for the slag blow can be from 150 to 300 minutes with an additional 45 to 100 minutes for charging matte and reverts and skimming slag.

(b) Finishing or Copper Blow - is the final step during which the remaining sulphur is driven off as SO_2. Air is blown through the charge until the final blister copper is low in sulphur (below 0.1%) and oxygen (below 0.8%).

At this point the blister copper is transferred to the next step in the process which is normally fire refining to anode copper in preparation for electrolytic refining.

The copper blow normally requires 160 to 300 minutes.

It should be pointed out that during the slag blow molten matte is charged to the converter. The converter is then rolled into the stack for blowing, after which flux will be added to form a slag, which is then poured into ladles. Additional furnace matte will then be charged and the process repeated until the charge of copper has been made up.

Converting of nickel matte follows steps similar to that outlined for

copper, particularly during the slag blow. In the nickel industry, however, the second stage is replaced with what is called the "finishing" blow where the iron and sulphur are adjusted to produce a Bessemer matte which is suitable for the next stage of refining. For instance, at Inco's Copper Cliff smelter this matte is low in Fe and slightly deficient, on a stoichiometric basis, in sulphur to meet the requirements of the Matte Separation Process. At Thompson, Manitoba the Bessemer matte is cast directly into anodes for refining.

The principal function of the converter then is to remove iron and adjust the sulphur in the final product to meet the requirements of the next process step. At the same time some other impurities can be removed along with the iron and sulphur. The converting operation is normally a batch process which produces an intermittent flow of relatively low strength SO_2 gas. In addition, turning the shell in and out of the stack during the cycle, for charging and skimming, generates emissions to the workplace. A typical sulphur balance, such as the one given below for a modern copper smelter, shows that the common Peirce-Smith converter is the main contributor to SO_2 in the work-place.

TABLE 1 ESTIMATE OF THE DISTRIBUTION OF SMELTER SULPHUR EMISSIONS TO ATMOSPHERE (1)

Source	% of Sulphur in Concentrate Emitted to Working Environment	External Atmosphere	Total Distribution
Dryer for charge preparation	minimal	0.3	0.3
Launders and matte transfer system	0.3	-	0.3
Leakage from smelting furnace	0.4	-	0.4
Leakage from Peirce-Smith converters	2.5	-	2.5
Anode furnace offgas	minimal	0.1	0.1
Single contact sulphuric acid plant tail gas	-	2.5	2.5
Total	3.2	2.9	6.1

In an effort to reduce emissions to the workplace and improve the gas flow to the sulphur fixation plant, several types of converters have been developed and are in operation in various smelters around the world.

4 COPPER AND NICKEL CONVERTERS

The Peirce-Smith converter is the most common converter in the industry and is used in 93% of the copper and nickel smelters surveyed recently by the American Institute of Mining and Metallurgy (A.I.M.E.). However, other converter types are in use, namely:

(1)	Hoboken syphon converter	4 smelters
(2)	Top blown rotary converter	3 smelters
(3)	Mitsubishi continuous converter	2 smelters

The top blown rotary converter, or Kaldo as it is called in Europe, treats matte on a batch basis and produces a variable gas stream, similar to the Peirce-Smith and Hoboken. The Mitsubishi converter produces a continuous flow of a relatively uniform strength offgas.

4.1 PEIRCE-SMITH CONVERTER

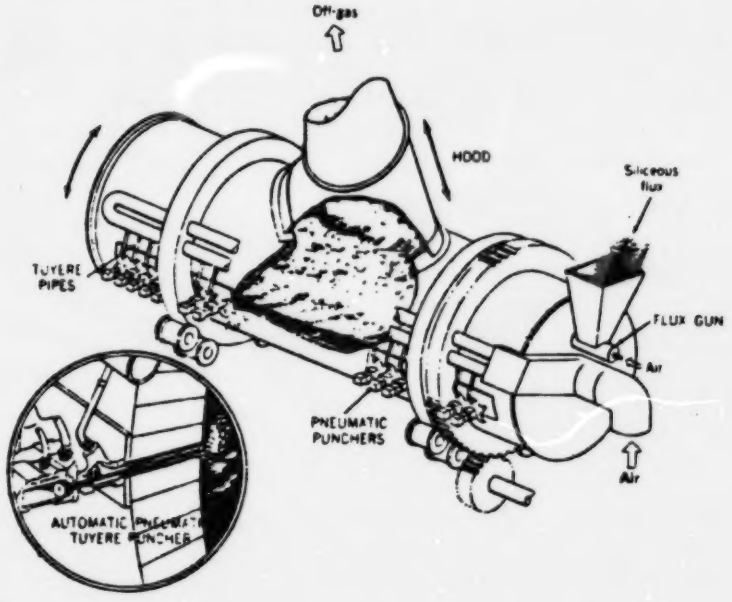
The conventional Peirce-Smith converter consists of a horizontal cylindrical steel shell, lined with refractory, which can rotate to discharge gas into a primary hood or cast molten material to ladles, as shown in Figure I.

Air, or oxygen enriched air, at between 12 and 16 psi (82.7 to 103.4 kPa) is fed through the bustle pipe and the submerged tuyeres into the molten bath. When the shell is turned out of the stack for charging matte or skimming, the air flow is shut off as the tuyeres leave the bath.

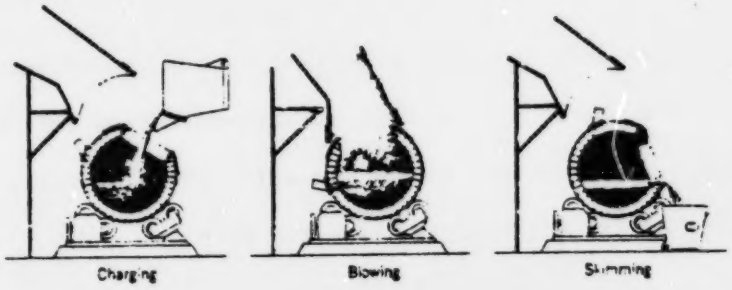
While blowing, accretions build up around the mouth of the tuyere and are cleared away with punch bars. Punching is required on a regular basis while the converter is blowing, or "on tuyeres", as it is sometimes called.

FIGURE I

CONVENTIONAL PEIRCE-SMITH CONVERTER



View of horizontal side blown Peirce-Smith converter used in copper and nickel industry.



Steps in the converting cycle and position of the converter shell, relative to the hood, for each step. (2)

The cycle time required to treat a charge will vary with the size of converter and whether or not oxygen enrichment is used (e.g. normally between 23 and 28% O_2), the grade of matte produced in the smelting furnace, crane service, etc. However, a typical cycle would be:

	Typical Time in Minutes	Operation	Offgas Position
	0		
	20	Charge ladles of 56% Cu matte to make up basic charge	Out of stack
		Add some flux	
	45	First slag blow	-
	20	Skim slag, charge additional matte and flux	Out of stack
	40	Second slag blow	-
	20	Skim slag, charge additional matte and flux	Out of stack
	30	Final slag blow	-
	15	Skim slag and add reverts, depending on temperature	Out of stack
End of slag stage	190		
	40	First copper blow	-
	5	Add reverts or scrap, depending on temperature	Out of stack
	40	Second copper blow	-
	5	Add reverts or scrap for temperature control	Out of stack
	30	Third copper blow	-
	15	Skim slag and add relatively clean scrap if coolant required	Out of stack
	10	Finishing blow to adjust sulphur and oxygen content	-
	30	Transfer blister copper to anode furnaces	Out of stack
End of copper stage	175		
Total time	365		

The time for a converter cycle is very dependent on crane service, since all matte, cold dope, etc. must be charged by crane and the ladles of slag must be removed by crane. Crane availability therefore is a key factor in a conventional converter aisle. In addition, matte grade is a governing factor.

A summary of the operating data for Peirce-Smith converters in Canadian smelters is given in Table 2.

4.1.2 Emissions. Gaseous and particulate emissions are generated during the converter cycle when

(a) molten matte is being charged;

(b) the tuyeres are entering or leaving the bath and the air is still on;

(c) the primary hood and offgas system do not have sufficient capacity to handle the volume of converter gas.

The design of the primary converter hood is the critical factor in controlling fugitive emissions. Older designs allowed for at least 200% in-leakage to provide initial cooling of the offgas. Fugitive emissions are very difficult to measure but some tests indicate that as much as 5% of the sulphur in the matte will bypass the primary hood and escape to the converter aisle while a copper converter is blowing. An additional 2% will occur when the converter is rolled out of the stack.

For this reason a number of improved hood designs have been developed in recent years for the Peirce-Smith converter. These are discussed in a subsequent section.

TABLE 2

SUMMARY OF PEIRCE-SMITH CONVERTERS IN CANADIAN SMELTERS (3)

	Inco Metals Copper Cliff (Copper Circuit)	Falconbridge Nickel	Gaspé Copper	Noranda	Hudson Bay
Number of Converters	5	4	2	5	3
Size in feet	13 Ø x 35	13 Ø x 30	13 Ø x 30	13 Ø x 30 & 14 Ø x 32	13 Ø x 30
Average Blowing Rate - SCFM					
Slag blow	18,000	18,000	22,000	23,000	20,000
Finishing blow	20,000	-	22,000	22,000	16,000
Average Blowing Rate - Nm^3/hr					
Slag blow	30,600	30,600	37,400	39,100	34,000
Finishing blow	34,000	-	37,400	37,400	27,200
Oxygen Enrichment - %					
Slag blow	28	25	none	none	none
Finishing blow	28	none	none	none	none
O_2 efficiency	93	95	80	95	76
Matte Grade - %					
Cu	45	8.6	40	74.4	35
Ni	1.5	14.8	0.05	-	0.01
S	25	24.7	23	19.8	23
Blowing Time - Minutes					
Slag blow	320	450	480	155	385
Finishing blow	210	78	90	285	165
Average Time in Stack - %	40	37	85	64	65

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4.2 HOBOKEN SYPHON CONVERTER

In order to overcome the problem of emissions to the workplace during blowing, Métallurgie Hoboken developed the syphon converter which draws the gas off from the end of the converter.

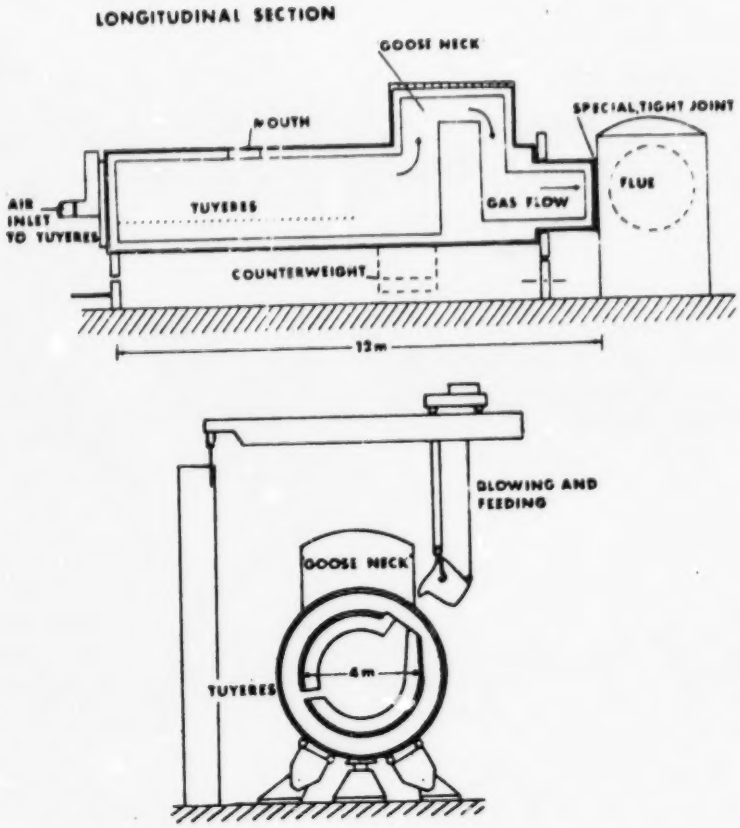
The longitudinal section, in Figure II, shows the "goose neck", or syphon, offtake which permits the collection of gas during the charging of matte or cold dope, as well as during the blow periods. With the Hoboken design, matte and dope are normally charged while the converter is blowing thus increasing the time in stack. By maintaining a slightly negative pressure at the converter mouth, there is no need for a primary hood; however, the Hoboken must be blown more gently to avoid splash into the syphon and to maintain this negative pressure at the mouth.

The operation of the Hoboken converter is similar to that of the Peirce-Smith converter as described in the previous section. Air, or oxygen enriched air, can be used and the tuyeres must be punched as is the case with the Peirce-Smith converter.

The use of a syphon to collect the offgas and the fact that a very slight negative pressure must be maintained at the mouth, limits the blowing rate to the design conditions. Consequently the cycle time can in some cases be longer with the Hoboken converter.

FIGURE II

HOBOKEN SYPHON CONVERTER



Side and end views of the Hoboken converter (4)

The cycle for a Hoboken converter treating a 47% Cu matte at Paipote is (5):

	Time in Minutes	Operation	Offgas Position
	0		
	10	Charging ladles of 47% Cu matte, add some flux	Out of stack
	130	First slag blow	-
	10	Skim slag	Out of stack
	100	Second slag blow, charge matte and flux	-
	10	Skim slag and clean mouth	Out of stack
End of slag blow	260		
	170	Copper blow, add reverts and scrap as required for temperature control	-
	30	Skim slag and transfer blister to anode furnace	Out of stack
End of copper blow	200		
Total cycle	460		

The complete Hoboken cycle can be slightly longer than for an equivalent Peirce-Smith operation.

Since the Hoboken converter can be charged while blowing, the offgas flow, particularly with two or more converters operating, will be more uniform and at higher average SO_2 strength than will be the case with conventional converters. Calculated exhaust gas strengths in the range of 11% SO_2, during the slag blow, and 13% during the copper blow have been reported (5). However, with some time out of stack and in-leakage through the mouth and the flue system, the range will be closer to 7-10% SO_2 in actual practice at the acid

plant. However, based on the above cycle, the converter is only out of stack 13% of the cycle time.

The Hoboken syphon converter is presently in use in four copper smelters and is attractive for treating higher grade matte and therefore has not been considered for nickel smelting.

4.3 TOP BLOWN ROTARY CONVERTER (KALDO)

The top blown rotary converter, or Kaldo, was originally developed for use in the steel industry and has recently been adapted for use in the nonferrous industry where its particular features are required. It differs from the more conventional converter types in that air is blown onto the bath, rather than through it, and the shell can rotate while blowing. In addition, oxidation as well as reduction can be carried out in the same vessel by adjusting the blow mixture. It is a very flexible unit and is used as a primary smelting process as well as a converter.

At the P.T. Inco Indonesia smelter at Soroako, three TBRC converters are used to produce a 79% Ni matte for further refining in Japan and Europe (6). Two units are in operation at Copper Cliff to process smelter intermediate products in preparation for the pressure carbonyl leach. The top blown rotary converter is also used in Belgium to reduce a calcine with coal to produce blister copper. Up to this year a TBRC was used at Afton, British Columbia to smelt and convert a very high grade copper concentrate with low sulphur content to blister copper.

Currently Boliden Metall AB is using a 3.6 m diameter unit to smelt and convert copper concentrates at its Rönnskär smelter in Sweden (7). A second

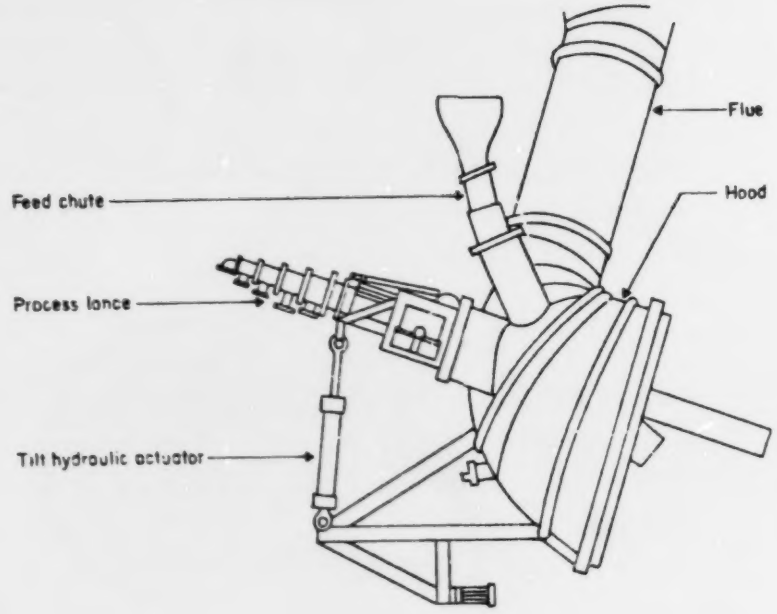
unit is used to produce bullion from lead residues and Boliden has carried out tests in the same furnace smelting lead concentrates.

The vessel itself is shown in cross-section in Figure III. A water cooled lance is used to blow air, oxygen, or oxygen enriched air or fuel directly onto the bath. In cases where the unit is used for smelting, the concentrate can be charged through the lance or through a separate chute. During the blow periods the vessel is rotated at about 5 rpm to promote mixing and maintain a uniform temperature. In the converting of nickel matte, the rotation will be closer to 20 rpm as is the case at Soroako (6).

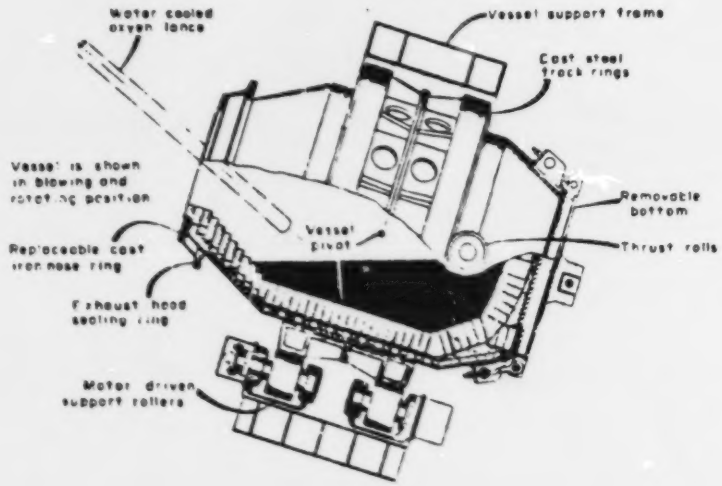
The converter is a refractory lined steel shell mounted in a support frame containing the rotational and tilting drive systems. These are complex mechanisms and contribute to the capital and maintenance costs of this process.

The lance and flux chute are mounted in the primary hood which covers the converter mouth when in the blowing position. Since the vessel rotates during blowing, splash and build-up at the mouth is continually worn off and a relatively tight fit can be maintained between the hood and the converter.

FIGURE 111



Swing hood and lance assembly for a top blown rotary converter, or Kaldo (3)



Cross-section of a top blown rotary converter, or Kaldo (8)

A typical cycle for a Kaldo smelting concentrate, as done by Boliden at Rönnskär (7), would be:

	Time in Minutes	Operation	Offgas Position
	0		
	180	Smelting concentrate for initial charge	-
	30	Skim slag	Out of stack
	120	Smelt additional concentrate	-
	30	Skim slag	Out of stack
End of smelting	360		
	90	Convert 65% Cu matte (1st slag blow)	-
	30	Skim converting slag	Out of stack
	30	Converting to white metal (2nd slag blow)	-
	35	Skim slag	Out of stack
	105	Copper blow	-
	45	Transfer blister copper to anode furnace	Out of stack
End of converting	335		
Total time	695		

The Kaldo is a very efficient converter and, in the converting cycle itself, is out of the stack only 33% of the time compared to approximately 36% for a typical Peirce-Smith cycle as described previously. As it is top blown there is no need for punching, and the rotation during the blow promotes the converting reactions and removal of volatile impurities.

Depending on whether or not oxygen enrichment is used, the gas strength in the converter itself will be in the range of 18% SO_2. Once it enters the hood and in-leakage is taken into account, the strength will drop to the 10 to 12% SO_2 range. The gas flow, however, will be variable as is the case with the conventional converter.

4.4 MITSUBISHI CONTINUOUS CONVERTER

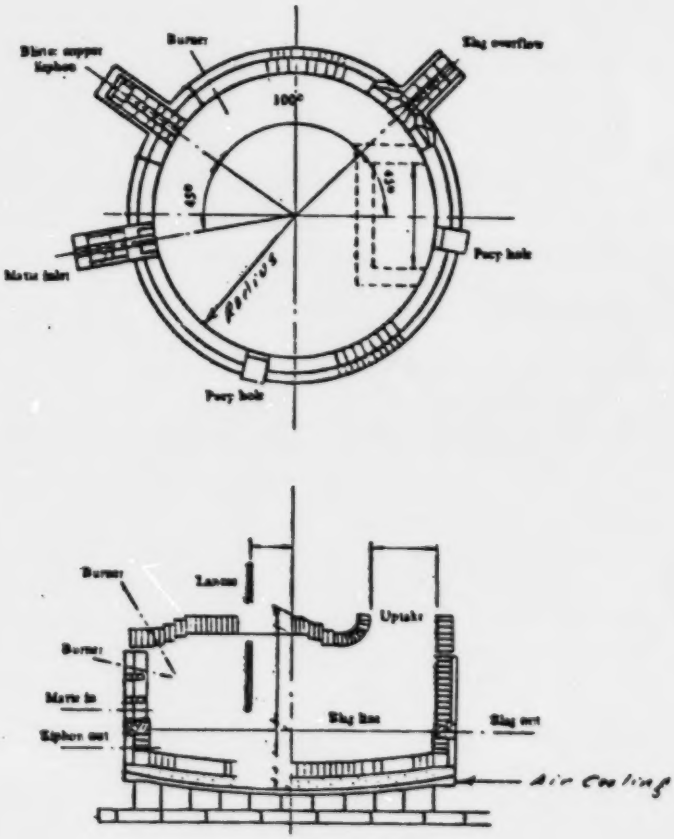
The Mitsubishi continuous smelting process includes a converting furnace which to date is the only truly continuous converter in commercial operation. This converter is in operation in the continuous copper smelters at Naoshima, Japan (9), and at Timmins, Ontario. It has also been considered for the treatment of high grade matte from more conventional smelting furnaces.

The furnace, shown in Figure IV, is a stationary unit and uses stainless steel lances to continuously top blow a bath of 60 to 65% Cu matte. It consists of a refractory lined steel shell, with an air cooled hearth and copper cooling blocks in the side walls. The roof is suspended and can be an arch or flat.

Several lances, depending on the required blowing rate, direct oxygen enriched air onto the centre of the bath. This creates considerable turbulence and converts the continuous flow of matte to blister copper. Since there is no end point, or distinct blow periods such as the slag and copper blows, it is necessary to over-oxidize the bath to produce a reasonably low sulphur blister. The resulting slag is high in Cu_2O and Fe_3O_4. In order to maintain fluidity and a continuous overflow of slag, a limestone flux is used rather than the normal silica flux. Blister copper flows continuously, through a syphon, to a holding furnace.

Unlike the top blown rotary converter, the lances are not water cooled and must be replaced on a routine basis, as they are consumed. The converter does not rotate and mixing is achieved through pneumatic agitation of the bath.

FIGURE IV



Plan and side views of the Mitsubishi continuous converting furnace (9)

Since the converting process in this case is continuous, the converter is "in the stack" effectively 100% of the time, and thus appreciably reduces the 2.5% emission to the workplace shown previously in Table 1. The offgas flow then is uniform, in the range of 230 to 250 Nm^3/min (8200 to 8800 scfm) and will contain 12 to 15% SO_2 in the uptake. Dilution from soot blowing, etc. will reduce the strength to the 7 to 9% SO_2 range at the electrostatic precipitator.

From an environmental point of view, the continuous converter is the ideal unit since it

(a) is never out of stack

(b) is a stationary unit and fugitive emissions can be contained

(c) produces a relatively high strength offgas.

There are however disadvantages with the continuous process. The elimination of impurities such as Pb, Bi, As, etc. is limited due to the lack of the conventional cycle, with a definite end point at which the oxidation potential and temperature can be increased to the level required to remove these elements. The large pieces of high-copper smelter reverts cannot be returned to the furnace as cold dope. The use of alloys for lance material introduces contaminants such as Ni, at the end of the process. Finally, the blister copper is relatively high in sulphur (normally over 0.5% S) which contributes to fugitive emissions during ladle transfer.

4.4.1 Emissions. Gaseous and particulate emissions are appreciably reduced with the use of the Mitsubishi continuous converter, due to the fact that it is a stationary furnace.

The hood, or uptake, in this case, is essentially part of the furnace

and leads directly into a waste heat boiler. Providing the exhaust fan creates sufficient draft, there is no emission to the workplace and the amount of in-leakage, and resulting gas dilution, is reduced compared with the more conventional systems.

Matte is fed through a covered launder and slag is laundered to a granulation tank, each of which minimizes fugitive emissions during material handling. With proper hooding and draft on the ventilation system, it should be possible to maintain the working environment above such a converter at less than 10 ppm SO_2.

5 CONVERTER HOODS

In order to collect the offgas from a conventional Peirce-Smith converter, a number of primary hood designs have been developed. It has not been necessary to develop similar hoods for the Hoboken, Kaldo or Mitsubishi converters, since the design of each includes the collection and containment of the process gases.

Originally, the primary converter hood was designed to allow for a significant inflow of ambient air, to assist in gas cooling and provide a good view of the flame by the operator (skimmer) for control. However, current concern for the working environment and increased gas strength have resulted in tighter hood designs.

Initially, water cooled hoods were developed by Noranda Mines, Boliden Metall and others. With reduced in-leakage, water cooling was necessary to withstand the higher gas temperatures of 800 to 900°C. Even with the water cooled hood, a gap between the hood and the converter shell of 0.1 m (4 inches) was necessary to allow for build-up of accretions and to avoid contact when the shell was turned out.

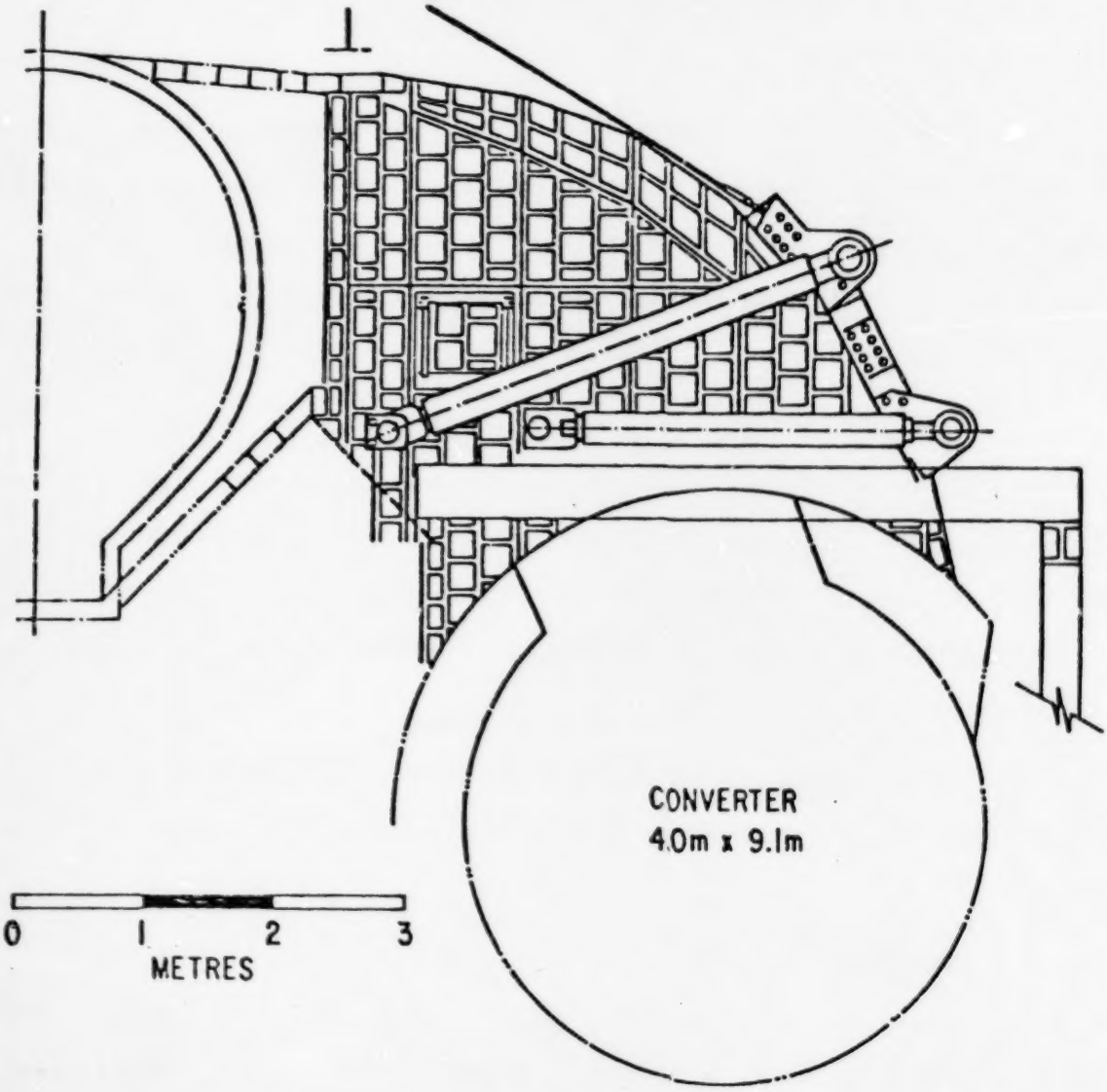
Water cooling can be hazardous and has proved to be a considerable maintenance item, with the result that new designs have been developed in recent years.

5.1 NORANDA WAFFLE HOOD

In 1980 Noranda installed a waffle hood at their Horne smelter. The unit is shown in Figure V, and consists of cast stainless steel panels bolted

FIGURE V

NORANDA WAFFLE-TYPE CONVERTER HOOD WITH GATE LIFTING ARMS. (10)



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together (10). The flanges then provide radiation cooling and an elaborate water cooling system is no longer required.

A door, raised by cable, allows the converter to be turned out to receive matte, scrap and to skim slag. The design permits the converter to turn far enough to remove the tuyeres from the bath before it is necessary to open the door. Consequently, gas and particulates are not blown out into the converter aisle as is the case with the conventional hood.

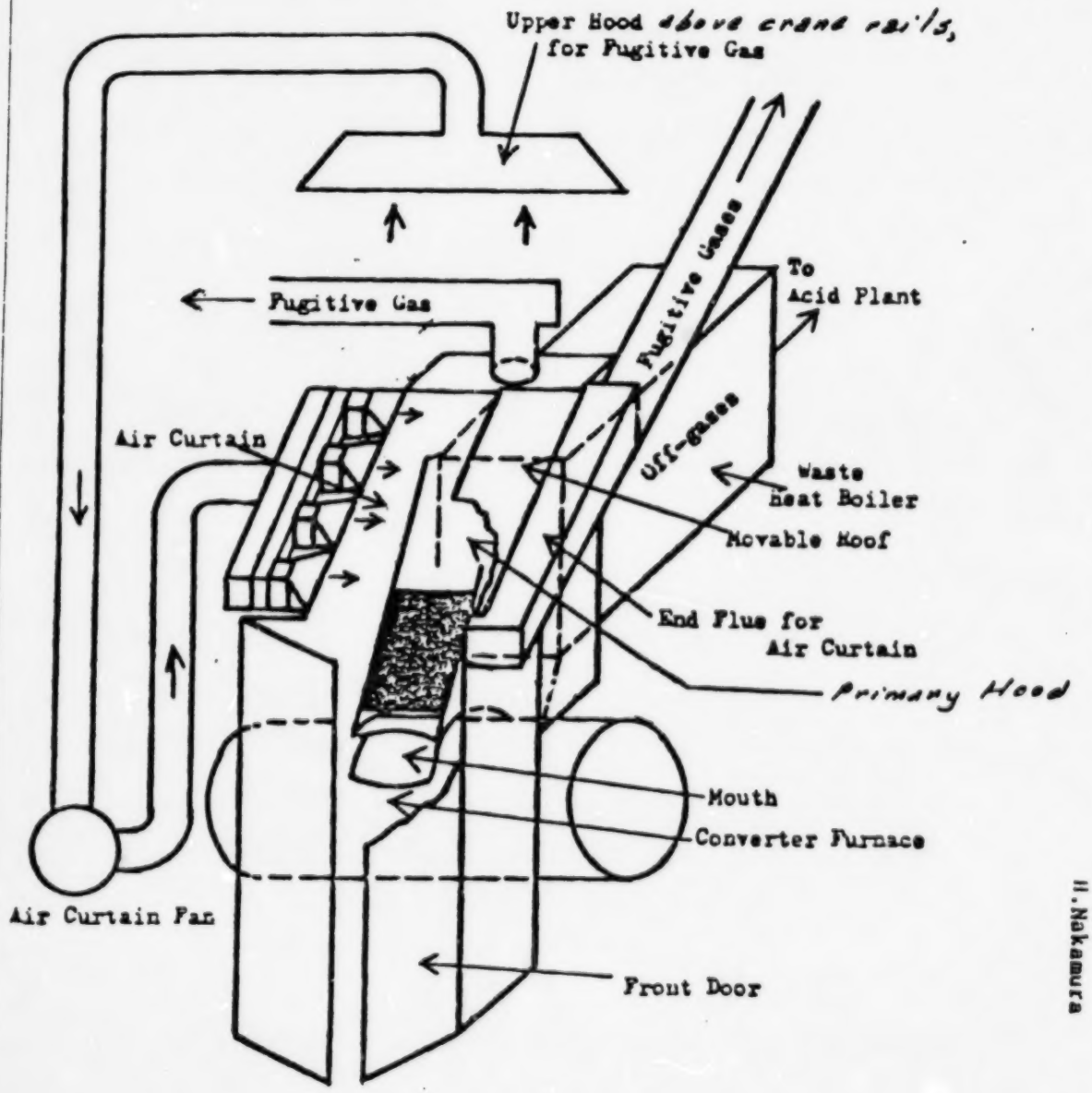
Fugitive emissions, which result from the charging of matte to the converter, are partially collected in the hood rather than being emitted to the aisle as is the case with the older design. With the door closed during skimming, some of the fugitive emissions are drawn into the hood, but the system is not as positive as some of the alternatives used in Japan, particularly with the cross-currents common in most converter aisles.

At present the waffle hood has reduced the in-leakage to 150% of the offgas volume and this could probably be reduced to 110 or 120% by closing the gap between the hood and the shell. However, the blowing rate would have to be carefully controlled to minimize splash and the converter mouth, or collar, would have to be kept very clean. The lower blowing rate would of course reduce the converter capacity as is the case with the Hoboken converter.

5.2 MITSUI CONVERTER HOUSING

Boliden Metall AB in Sweden were the first to install a secondary hood to reduce in-leakage and collect fugitive emissions. Since then, the Japanese smelters have developed various designs for double hood enclosures. One system which is very effective is that developed by Mitsui Mining and Smelting and in use at their Tamano smelter, Figure VI (11).

FIGURE VI



Mitsui Converter Housing System (11)

The primary hood is water cooled on the top and back with corrugated sides to provide radiation cooling. Cooling on the sides employs the same principle as Noranda's waffle hood. The hood itself is fixed and has a sliding door on the front to permit the charging of matte and reverts. The gap between the hood and the converter shell is 3.5 to 4.0 cm. This is a very close tolerance and the blowing rate is kept at less than 550 Nm^3/min (19,500 scfm) to minimize splash, i.e. about 20% below the actual capacity of this particular converter.

The secondary hood, or enclosure, is designed to contain and remove the fugitive emissions which bypass the primary hood.

Converter offgas: Volume - 1,170 Nm^3/min (41,000 scfm)

Precipitator outlet: % SO_2 - slag blow = 6.3

- copper blow = 8.8

The enclosure consists of swing doors on the front and a moveable roof which when open activates an air curtain, to accommodate the crane cables. Emissions during the blow, charging and skimming are thereby contained and vented to the fugitive gas cleaning system. The upper hood is located above the crane rails and collects those emissions which are not contained by the air curtain.

It is estimated that the Tamano system captures about 95% of the converter gases, and with the upper hood, effectively contains emissions to the exterior environment. Above the converter, however, the atmosphere will average about 50 ppm SO_2 and can go as high as 300 ppm when the converter is out of stack and matte is charged. From this it would appear that the air

curtain is not as effective in containing emissions as are solid doors. This supports the experience of Nippon Mining who abandoned their air curtain hoods at their Hitachi smelter in favour of a design similar to the Mitsui system.

Converter operations are scheduled so that fugitive emissions are drawn from only one converter at a time. The volume of fugitive gases from one converter will average about 267 Nm^3/min and contains in the order of 300 ppm SO_2. The concentration can increase to 500 ppm or more for short periods when turning in or out of stack or charging matte.

As is the case with other Japanese systems, the Mitsui enclosures are complicated and require close control of operations, a high level of maintenance, and very good housekeeping in the plant.

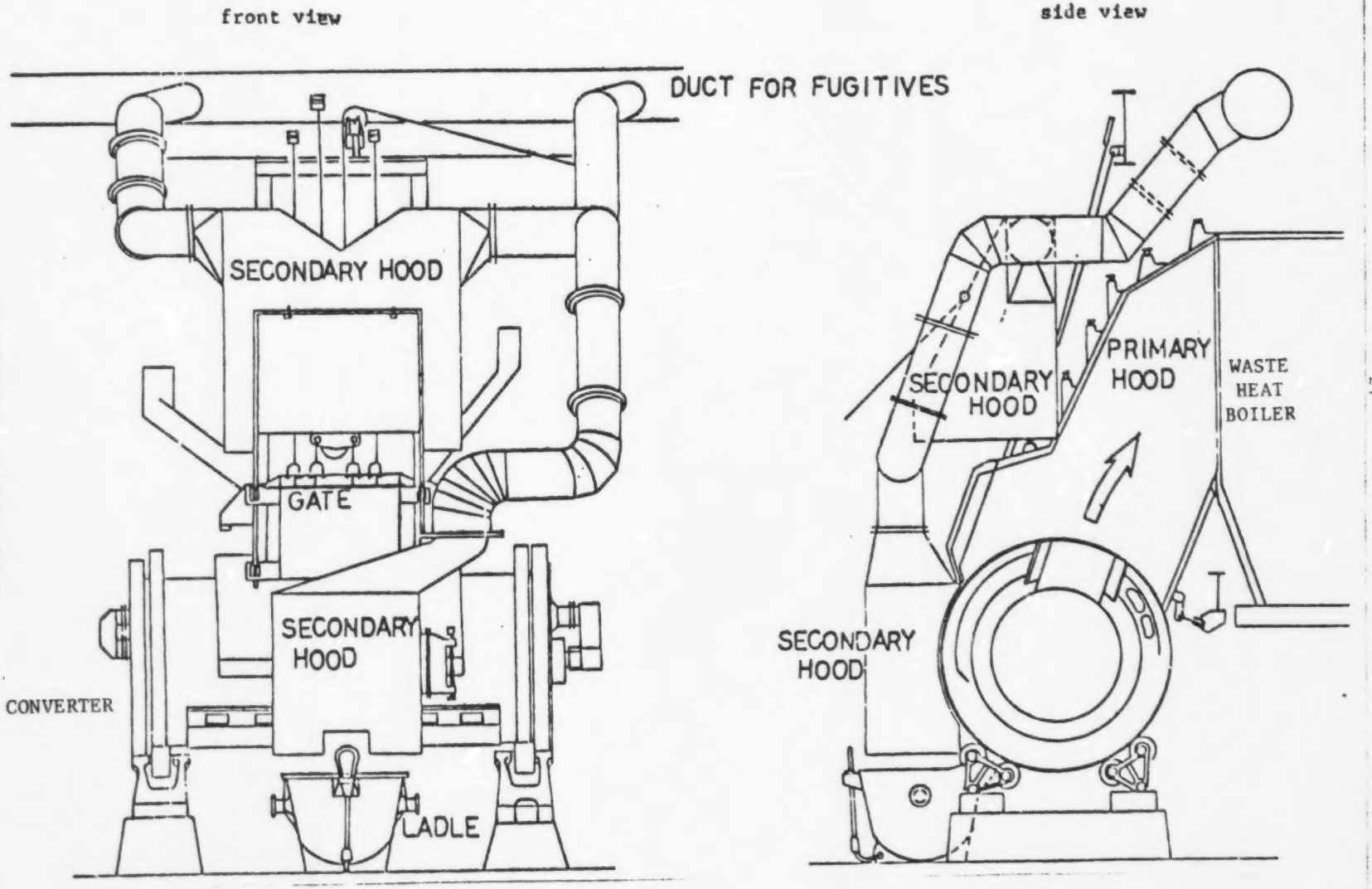
5.3 SUMITOMO HOOD SYSTEM

The Toyo smelter of the Sumitomo Metal Mining Co. Ltd. near Niihama, Japan, uses individual secondary hoods to contain fugitive emissions (12). This is perhaps the cleanest copper smelter operating in the world, and their converter hood system makes a significant contribution to environmental control.

Rather than totally enclose the converter mouth and primary hood area, Sumitomo uses separate secondary hoods to collect emissions from the primary hood gate, or door, and the ladle area (Figure VII). The ladle hood swings out of the way to allow crane access and the upper hood has a flexible front which deflects under pressure of the crane cables when charging matte or reverts.

The primary hood is water cooled and the gate is cast iron with radiation, or waffle, fins. As is the case at Tamano, this hood fits close to

FIGURE VII



Sumitomo primary and secondary converter hoods (12)

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the converter shell and the gap at the sides is about 2.5 cm, which Toyo people maintain reduces in-leakage to the 100% level. The blowing rate is closely controlled at 600 Nm^3/min (21,000 scfm) to minimize splash and build-up around the mouth. Cold dope, for temperature control, can be added while the converter is in stack thus eliminating one period of high fugitive emissions.

The secondary hood system is activated as required by each converter. When in operation on any given converter, the average flow will be (13):

		Nm^3/min	SO_2
(a)	Secondary hood over mouth =	1,400	200-300 ppm
(b)	Hood over ladle (intermittent) =	700	0.5-1.0%
	Total ventilation gas volume =	2,100	

With the more localized hooding, this system draws more air than the Mitsui approach since it relies on sweeping the fumes into each hood, but in our opinion it is a more effective collection system. In terms of air moved and horsepower required, the Sumitomo system will have higher requirements than the Mitsui enclosure, but appreciably less than the 3,000 Nm^3/min required for a straight air curtain design as was used at Hitachi.

In the whole Toyo smelter the fugitive gas system consists of 29 local ventilation hoods and has a design capacity of 4,400 Nm^3/min (155,000 scfm) at 150 to 200 ppm SO_2, which is almost twice the volume of smelter process gases. By activating the ventilation hoods as required and maintaining close control of the various smelter operations, Sumitomo can control emissions with a relatively manageable total volume.

One advantage of the Sumitomo over the Mitsui design is that the use of separate secondary hoods should be easier to adapt to an existing converter aisle, than would the fixed Mitsui enclosure.

5.4 OTHER APPROACHES

There are a number of other variations of converter hoods used in the industry but the above, in our opinion, are the most successful approaches.

At the Rönnskär smelter in Sweden, the Kaldo converter is totally enclosed in a ventilated chamber (7), which is perhaps the ideal approach. This system is possible with the top blown rotary converter since tuyere punching is not necessary. In addition, the lance-primary hood system in the Demag design moves in and out, in a straight line, rather than swing, as is the case with North American units and this simplifies the enclosure design. With the Kaldo, the operator controls all operations from a control room which looks into the converter enclosure and it is necessary to enter the enclosure only to clean the mouth, take samples, and carry out maintenance. In each case the SO_2 and fumes are evacuated before an employee enters the enclosure.

Air curtains have been tested on a commercial basis but have been abandoned in the majority of cases. The Mitsui system, described previously, shows that the air curtain is not as effective as the solid door or enclosure, due to the thermals set up by the converter and the variable draft patterns in tall converter buildings. In addition, the entrainment of false air increases the volume of gas to be handled continuously to the 3,000 to 6,000 Nm^3/min range (106,000 to 212,000 scfm) and this requires a considerable amount of electric power.

6 CONVERTER GAS COOLING AND CLEANING

The offgas from a converter will be in the 1100 to 1200°C range immediately above the bath, but in-leakage around the primary hood and cooling of the hood itself will reduce the temperature to the 800 to 900°C range. A number of years ago the space between the primary hood and the converter shell was designed to allow an inflow of a significant volume of ambient air to provide initial cooling which would reduce the temperature to the 600 to 700°C range. Currently, however, converter hoods such as those described previously, are designed for closer fit and result in the higher hood temperatures.

6.1 GAS COOLING

Regardless of the temperature in the primary hood, the offgas must be cooled to the temperature acceptable to the dust cleaning equipment, normally 250 to 350°C for an electrostatic precipitator. It is important that the gas be cooled rapidly from 640 to 570°C to minimize the formation of SO_3 and several systems are currently in use. The conversion of SO_2 to SO_3 in a smelter gas depends on cooling rate and the presence of lead, zinc and iron oxides. The variable flow, fluctuating temperatures, etc. make SO_3 formation a particular problem in the converter gases which can result in severe corrosion problems and high maintenance costs. Gas cooling therefore is an important consideration to converting.

6.1.1 Radiation Coolers. Hairpin coolers, high velocity flues and similar devices are used for cooling converter gases. They have however some significant disadvantages, some of which result from the fact that the converter offgas varies significantly in volume and temperature as the converter cycles in and out of stack.

Radiation coolers have a definite surface area once the design is fixed, and the amount of heat removed is a function of surface area and ambient air conditions which can vary significantly throughout the year, particularly in a climate such as Canada's. Consequently, the more common radiation coolers do not

(a) rapidly cool the gas through the critical temperature range, resulting in increased SO_3 formation and are prone to the formation of sulphates and corrosion;

(b) permit adjustments to the cooling rate, making them less satisfactory for gases having a wide variation in temperature;

(c) readily allow for significant changes in the process or the operating schedule.

Corrosion and the lack of the necessary flexibility are the main disadvantages of the radiation cooler. They can be one of the less expensive systems to install; however, the capital cost saving can soon be eliminated if the installation does not operate as designed. In such cases the annual maintenance costs for the cooling system alone can increase significantly and place the smelter at an economic disadvantage.

Even under ideal feed gas conditions, the radiation cooler can be a significant maintenance item. At Naoshima, Mitsubishi used a hairpin cooler on their stand-by continuous converting furnace which produced a uniform flow of high strength gas. Corrosion of this cooler proved to be a very costly maintenance item and it was discarded as part of the recent smelter modifications.

6.1.2 Air-to-Gas Heat Exchangers. In order to control the amount of cooling and adjust to the feed gas temperatures, air-to-gas heat exchangers are used. By adjusting the air flow through the heat exchanger, some control can be exerted

on the discharge gas temperature.

Various systems are available but one is the double-walled flue. It is similar to the high velocity flue but has an outer wall through which a flow of cooling air is passed, controlled by the gas discharge temperature. Alternatively, hot air or ventilation gases can be fed to the outer chamber to maintain the flue above the dew point during shutdown periods.

While the double-walled flue works well in some European plants, it has given trouble at the copper smelter in Taiwan. The disadvantage of the double wall is that leak detection and repair can be difficult. In addition, relatively long runs can be required to achieve the desired cooling, and this expands the plant layout. In retrofit situations there is frequently insufficient room for a double-walled flue system.

In the latter case other designs of heat exchanger must be used. These are normally forced draft coolers and usually require substantial electric power to overcome the pressure drop in the system. Cleaning of the tubes can also be a problem in these units. For instance, at Kennecott's Garfield smelter converter gases are cooled in shot cleaned, air-to-gas heat exchangers. Dust build-up on the cooling tubes is removed with cascading shots; however, in practice the shot cleaning has been a problem area.

6.1.3 Waste Heat Boilers. Waste heat boilers are commonly used in Japan and have the advantage of rapidly cooling the gas through the temperature range most critical for SO_3 formation. This is, however, the most expensive method of cooling converter gases.

In a typical installation the gas leaving the primary hood will enter

the boiler at 700 to 800°C and be discharged in the 350 to 380°C range. Since the converter gas flow is variable, the boilers for all converters are connected through a steam accumulator and forced water circulation and the system is integrated with the waste heat boiler for the smelting furnace or a back-up boiler. Although complex, this arrangement permits any given boiler to maintain temperature and pressure when its converter is out of stack. Even so, it is necessary to carefully schedule converter operations so that no more than one unit is out of stack at any given time. In Japan close control of the blowing rate and cycle time is normal operating practice, whereas in North America such control has been less successful.

Due to the complex system required, boilers have not been widely adopted by the industry in North America. Kidd Creek Mines at Timmins does have a waste heat boiler on its continuous converting furnace (14). While this installation is operating satisfactorily, the removal of accretions and control of build-up on the tubes is more of an operating problem than is the case with a smelting furnace waste heat boiler.

For a conventional converter, a waste heat boiler is a very efficient cooling system, but the costs are extremely high and normally cannot be justified except in special cases where energy, particularly electric power, costs are high, as is the case in Japan. In spite of the increased capital cost, boilers are used on the converters at the Phelps Dodge Hidalgo smelter.

6.1.4 Other Systems. A simple method of cooling an offgas is evaporative, or quench, cooling using high pressure atomizing water nozzles. Since one kilogram of water absorbs about 590 kilocalories during evaporation, hot gases

can be cooled with a relatively small nozzle installation in the converter flue. The cooling can be controlled to maintain the required exit gas temperature by adjusting water flow, and the system proved very effective on the top blown rotary converters at Copper Cliff. It does however increase the moisture content of the gas which increases the amount of weak impure acid to be disposed of in an acid plant.

Other systems include water cooled uptakes such as those installed on the Hoboken converters at Inspiration, but all the systems in present operation have problems of one type or another resulting primarily from the variations in gas flow.

6.2 GAS CLEANING

In any metallurgical operation the offgases are normally cleaned in two stages prior to entering a sulphur fixation facility. The first is the "hot" gas cleaning which can include a waste heat boiler, cyclone, electrostatic precipitator, or if sufficiently low in temperature, a baghouse or scrubber. The second is "wet" gas cleaning and, in North America, this step is normally part of the metallurgical type sulphuric acid plant or other sulphur fixation facility. The two stages are covered in a separate study being carried out by Fenco Engineers Inc. (47SS-KE145-3-0255).

As pointed out in our sulphur report (EPS-3-AP-79-8) the variable flow of relatively low strength converter gases is, in practice, only suitable as feed for a sulphuric acid plant.

6.2.1 Flues and Cyclones. Initial gas cleaning, that is the removal of coarse particles, takes place in the ducts and balloon flues leading from the

converter primary hood. In cases where a boiler is used, it will of course be the initial gas cleaning unit.

Depending on the dust loading in the gas from the balloon flue, a cyclone might be used to further reduce the dust load on the electrostatic precipitator. Cyclones are not, however, commonly used in the converter gas system since the dust loading is usually lower than is the case in the smelting circuit and they increase the pressure drop.

Dusts collected in the flue system will be high in Cu, Ni, etc. Light fume, such as the oxides of lead, zinc and arsenic, the latter being temperature-dependent, will pass on to the next stage.

6.2.2 Electrostatic Precipitators. The electrostatic precipitator is the most common method of cleaning converter gases. Frequently these gases are combined with those from the smelting process and cleaned in a common bank of precipitators. In older smelters a settling chamber was frequently used, but these did not have the same collection efficiency as a precipitator (i.e. normally 99%) and most have either been converted to or replaced by electrostatic precipitators. The settling chamber, however, had one advantage in that gas temperature was not critical and it could handle gases above the 250 to 350°C range common for the precipitator.

Precipitators work on the principle that fine particles, suspended in the gas, can be given a charge and attracted to a collector carrying the opposite charge. Consequently, fine dust and fume such as lead, zinc and, depending on temperature, arsenic oxides can be removed in a hot precipitator. The dust loading at the precipitator inlet will be in the range of 2 to 5 g/Nm^3,

with the slag blow producing the higher level. Highly volatile elements, such as mercury and selenium will, however, pass through the hot precipitator and be collected in the wet gas cleaning circuit or in the acid plant itself.

6.3 SUMMARY

Cooling of converter gases starts in the primary hood and is carried out in a series of stages designed to lower the temperature to less than the 360°C level acceptable for an electrostatic precipitator, while maintaining the gas above the dew point.

The object of the cooling-cleaning system is to produce a relatively clean gas for further treatment, and to return the dust to the smelter circuit to maintain the recovery of metal values.

7 SULPHUR FIXATION OF CONVERTER GASES

The relatively low strength and varying volume of converter gases make processing to sulphuric acid the only practical alternative. The main problem to be overcome in the acid plant is the variation in SO_2 content, the fluctuating volume while the converter is in stack, and the interruption in flow when out of stack, or on stand-by due to production or environmental cutbacks.

7.1 INFILTRATION

The definition and measurement of ambient air drawn into a flue system is very difficult to establish accurately. The major portion is usually drawn in under the primary hood and "tight" hoods are designed to fit as close as practical to the converter shell.

There are, however, other sources of infiltration, or in-leakage, resulting from

(a) lancing of ducts, or soot-blowing with air in the case of boilers, heat exchangers, etc.;

(b) leaks at expansion joints, in ductwork, etc.;

(c) seal or purge air around soot blowers, precipitator insulators, etc.

The volume of air infiltrated from these sources can be substantial and not only reduces gas strength but provides additional gas cooling.

A well maintained, relatively tight flue system can maintain a strength of 5 to 6.5% SO_2 at the outlet of the precipitator during the slag blow, and 7 to 8% SO_2 or more during the copper blow. The design of the flue system, oxygen enriched tuyere air and other factors will all govern the gas strength

at the acid plant. In some cases, particularly older smelters, it is often difficult to maintain an average strength of much over 4% SO_2.

7.2 VARIABLE GAS FLOW

Sulphuric acid plants, treating only variable gas flows from conventional converter operations, must be designed for the maximum and minimum volumes and the maximum and minimum SO_2 content. This results in an expensive plant and a production cost of 55% more than a comparable plant treating a continuous gas flow (15).

Where two or more converters are required in a smelter, some scheduling of their respective charging, slag and copper blows can be established to reduce the variation in gas fed to an acid plant. The amount of control is limited by a number of factors, such as:

(a) matte supply;

(b) crane availability to charge matte, cold dope, and remove slag;

(c) production scheduling which may call for cutbacks;

(d) cutbacks in operation for environmental reasons;

(e) operator error;

(f) maintenance and repairs, when a stand-by converter is not available.

In practice converter scheduling provides only limited benefit in levelling out the gas flow.

The development of such units as the Hoboken converter was based on increasing time in stack and providing a more uniform gas flow than is normal with the conventional Peirce-Smith converter. The flexibility of the top blown rotary converter enables the operator to exert more control over the converting

cycle and thus maintain the required schedule.

The ideal conditions result from the use of a continuous converter as incorporated in the Mitsubishi continuous process in operation at Timmins, Ontario and Naoshima in Japan.

7.3 LIMITATIONS

While converter gas can and is being processed to sulphuric acid, the variable feed gas is less desirable, from the acid plant point of view, than a continuous source. Where possible, converter gases are blended with a continuous gas stream from the smelting process.

In the absence of a continuous source of SO_2 gas, at least two operating converters are required to feed an acid plant. The converter operation is then essentially dictated by the acid plant requirements which may not conform to the metallurgical requirements. For instance, when converting a copper matte containing some nickel, a "washout" step can be required in the cycle which takes the converter out of stack longer than is normal in copper converting. The average time in stack at Copper Cliff is only about 40% compared to about 65% at Noranda and 85% at Gaspé. It is possible therefore that the converters cannot effectively carry out their metallurgical function, particularly with respect to impurity removal.

During periods of low gas strength, temperatures in the acid plant can drop, reducing conversion efficiency, and auxiliary heat must be supplied. This increases the operating cost of the acid plant.

7.4 FUGITIVE EMISSIONS

Tramp or fugitive emissions must be contained and collected for treatment if a metallurgical operation is to match the high level of containment common in Japan.

Table 1, given previously, shows that the conventional Peirce-Smith converter is the principal source of fugitive emissions in a modern, well maintained smelter. Tight fitting primary hoods and secondary hoods, or enclosures, are required to reduce fugitive converter emissions to less than the level shown in Table 1.

The volume of fugitive emissions collected in an enclosure or secondary hood system, such as those described in sections 5.2 and 5.3, will vary from 16,000 to 126,000 Nm^3/hr depending on the system selected and the time required for the ventilation of each point. Most of the systems used in Japan operate only as required at each location. Consequently while the volumes can be high, the fact that the demand is intermittent reduces the equipment and power requirements. Such is not the case where only air curtains are used in place of enclosures.

The fugitive emissions, once collected, are low in SO_2, normally 200 to 600 ppm and are frequently scrubbed with lime in such units as a turbulent contact absorber (TCA) to fix the sulphur as gypsum. These scrubbers will reduce the gas to less than 5 ppm SO_2, a level which is allowable for discharge to atmosphere in Japan. Other weak gas scrubbing systems are also used (16). One which offers particular advantages in controlling problems with lime build-up is the Dowa Mining aluminum sulfate process (17).

The disposal of gypsum presents little problem in Japan, which must import this material, but in North America disposal can be an impoundment problem. The Sulphur Development Institute (SUDIC) report for Energy, Mines and Resources dated September 19, 1983 (18) indicates that, in Canada, such products as gypsum will pose serious problems of disposition and cost.

The collection of fugitive emissions is greatly simplified when the major equipment is stationary and a continuous process is used. The results reported for the Kidd Creek continuous smelter at Timmins indicate that an overall sulphur containment of 99% can be achieved with a continuous process (14), compared to the less than 94%, using the estimated losses given in Table 1, for a more conventional process.

8 NEW AND EMERGING TECHNOLOGY

New processes recently put into operation or currently under development take into account the problems associated with the fixation of sulphur from conventional converter offgases. New converters, the combination of technologies, and direct smelting to blister are the options currently being considered and piloted by the industry; for instance:

New Converters:	Kennecott's Solid Matte Oxygen Converting (SMOC)
	Humboldt-Wedag's CONTOP Converter
Combined Technology:	Flash Smelting combined with the Mitsubishi Converting Furnace
Direct and Continuous Processes:	Mitsubishi Continuous Process
	Noranda Process Smelting to Blister
	Outokumpu Flash Smelting to Blister
	Reduction Smelting to Nickel Matte.

All the above, with the exception of reduction smelting, are directed towards the production of copper. It should be noted, however, that the dead roast-reduction process has been used for copper for a number of years and was known as the Brixlegg process. The principal has been used and is still being considered by others for various copper smelting alternatives. The top blown rotary converter, on the other hand, has been adapted by Inco for the treatment of nickel matte and smelter intermediates.

8.1 KENNECOTT'S SMOC PROCESS

The converting of solid matte with tonnage oxygen has been tested in the laboratory and evaluated from an engineering point of view (19).

This is a continuous process which converts high grade granulated copper matte to blister copper and produces a low volume of high strength gas (75% SO_2), comparable to that produced in the Inco flash furnace. The process is designed to use solid matte, consequently fugitive emissions during ladle transfer are eliminated and the converting operation can be located away from the smelter to simplify material handling and meet particular requirements in the sulphur market.

The continuous flow of a high strength gas overcomes one of the main disadvantages of conventional converters and provides the option of fixing sulphur as acid, liquid SO_2, or in particular cases as elemental sulphur.

The SMOC process is a unique approach to copper converting and its development through the pilot plant program will be watched closely by the industry.

8.2 CONTOP CONVERTER

Humboldt-Wedag of West Germany is piloting a Continuous Top Blown Oxygen smelting process (CONTOP) for the smelting of copper concentrates. It consists of oxygen flash smelting in a cyclone, a slag settling furnace, and a top blown continuous converter. The latter is similar in some respects to the Mitsubishi converting furnace described previously.

White metal flows by launder to the converting furnace. This is actually a combined converting and refining furnace. In the converting section, stationary lances blow an air-oxygen mixture onto the top of the bath. This results in over-oxidation of the copper which flows through a weir into the refining section where it is refined to anode copper by lancing with reduction

gases.

As in the SMOC process, the CONTOP converting furnace will produce a high strength SO_2 offgas on a continuous basis. A small test furnace has been installed in the new pilot plant in West Germany, but the test program will not start until 1984. Lance blowing and reduction to anode copper in one furnace will require considerable development work before this process can be considered for a commercial operation.

8.3 COMBINED TECHNOLOGY

The feasibility of converting a continuous flow of high grade matte (65% Cu) from a flash furnace has been investigated by one large U.S. producer. The Mitsubishi continuous converting furnace was assumed for this evaluation, but it is possible that the CONTOP unit could be used as well. The advantage of the former is that it is a proven unit on a commercial basis.

The combination of technology was suggested by us in the course of evaluating process options for a smelter project in early 1980. The object was to ensure that the converter gas, as well as the offgas from the smelting furnace, would be a continuous high strength flow. The elimination of ladle transfer of molten matte would significantly reduce fugitive emissions and assist in meeting roof line emission limits.

Either an Inco or Outokumpu flash furnace could be used, provided that a continuous flow of 60 to 65% Cu matte could be maintained. Although not tested in practice, the combination of technology offers a number of advantages and could well be considered for future smelter projects. Some plant tests,

however, will be required to ensure that the smelting furnace will produce the uniform flow of high grade matte essential for good converter control.

8.4 MITSUBISHI CONTINUOUS CONVERTER

The converting furnace has been described previously. The Mitsubishi continuous process is mentioned in this section since it is one of the two processes currently in commercial operation producing blister continuously from concentrate.

The main drawbacks, from an emission point of view, is the relatively high sulphur content (e.g. 0.5% S or more) of the blister which contributes to fugitive emissions during ladle transfer.

8.5 NORANDA PROCESS

The Noranda reactor can, operating in the blister mode, smelt and convert copper concentrate directly to blister copper in one vessel. The first few years of operation at the Horne smelter were in the blister mode, but since then both the Horne and Kennecott's Garfield smelter are operating in the matte mode.

The reactor is similar to a Peirce-Smith converter in that air, or oxygen enriched air, is blown in through tuyeres to smelt the concentrate, oxidize the iron and sulphur, and produce blister copper. Since the latter is in contact with "white metal" in the reactor bath, the final blister is relatively high in sulphur (e.g. 1.0 to 2.0% S) which results in fugitive emissions during ladle transfer to the anode furnace.

Due to the combination of several metallurgical steps in one vessel,

the offgas strength is in the range of 10 to 20% SO_2, at the reactor, depending on whether or not oxygen enrichment is used. One of the main drawbacks to the blister option is a reduced campaign life, that is the operating period between refractory repairs, of the order of 70 days. The latter is not too different from the campaign life of a conventional converter and this is why at least one stand-by converter is required in most conventional smelters.

The campaign life and other reasons account for the adoption of the matte, rather than the blister, option by Noranda and Kennecott.

8.6 OUTOKUMPU - BLISTER

In recent years Outokumpu Oy has adapted its flash smelting process to smelt concentrates directly to blister in a flash furnace. As is the case with the Noranda process described above, smelting and converting are carried out in the same furnace.

A special concentrate burner is used which ensures intimate mixing of the concentrate and the oxygen enriched air. The bulk of the metallurgical reactions take place in the reaction shaft and with certain concentrates, it is possible to produce blister copper directly. With others, it is necessary to produce an intermediate "white metal" layer which is converted to blister copper, using oxygen enriched air introduced through side wall tuyeres. As in the previous process, the blister copper contains 1 to 2% S, but the offgas is high strength and a continuous flow.

The Glogow copper smelter in Poland is presently smelting an unusual low-iron and sulphur, high-carbon and lead, concentrate directly to blister copper. Oxygen enriched air (65% O_2) is used to oxidize the iron, sulphur and

carbon producing blister copper directly. Copper not reporting directly to blister is recovered as a high grade matte in the slag cleaning process and converted in Hoboken converters. This is a special case but is a commercial example of flash smelting directly to blister copper.

8.7 INCO - REDUCTION SMELTING

In order to improve the capture and fixation of SO_2 from the electric furnace smelting process, Inco has tested, on a tonnage basis, the Reduction Smelting process. This test was carried out at its Thompson smelter where a fluid bed roaster and electric furnace were available.

Nickel concentrate is roasted, to eliminate all the sulphur normally removed in the smelting and converting operations, and to produce a continuous flow of reasonably strong gas (10 to 11% SO_2) as feed to an acid plant. The nickel oxide in the calcine is then reduced in an electric furnace, using coke, to produce the sulphur-deficient nickel matte (15 to 18% S). The converting operation, then, is only required to oxidize and slag off the iron, reducing the amount of sulphur removed in the converter to a fraction of the sulphur in roaster feed. Since Inco's downstream processing is based on a sulphur-deficient matte, sulphur removal is not required in the converter. The converter offgas, therefore, would contain less than 1% SO_2, compared to the higher SO_2 for the more conventional nickel converter operations.

The Inco system does not eliminate the conventional converter, and consequently retains the advantages of this unit, but it does reduce its role in sulphur elimination. The converter gas will still contain SO_2, and under Japanese regulations would have to be lime-scrubbed prior to exhaust to

atmosphere. There will still be emissions during ladle transfer of about 0.07 kg SO_2 per MT furnace matte; however, these emissions will be considerably less than the 2.9 for reverb matte. Consequently the fugitive emissions will be less than shown in Table 1, but not as low as would be the case with launder transfer in a continuous process.

The process is interesting and certainly reduces converter emissions. Also, it is the only significant development in nickel processing over the past few years.

8.8 LIMITATIONS

The development of new technology such as that described above, is directed towards the production of a continuous flow of high strength SO_2 offgas. Conventional converting technology is a batch process which produces a variable flow and strength of offgas.

The batch process permits control of the cycle time, final temperature, end point sulphur, etc. This flexibility allows the smelter operator to remove impurities such as arsenic, bismuth, lead and in copper smelting, nickel and cobalt at various points in the converter cycle. High copper scrap and reverts, which cannot be crushed, can also be digested during the converting cycle.

Impurity elimination and scrap return are limited when a continuous process is adopted which in turn will limit the application of new technology. The application of the above new processes to any specific operation will depend on the current and future impurity levels in concentrate and the need for flexibility in the smelter operation.

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